SYNTHETIC RUBBER

Things of science

Unit No. 249

received by a Group of Friends of Science; sponsored and distributed without profit by Science Service, the Institution for the Popularization of Science, 1719 N Street, N.W., Washington 6, D. C. Watson Davis, Director

This unit of THINGS of science consists of a vial of liquid latex, a plastic envelope of crumb rubber, a sample of compressed raw [illegible] a [illegible] [illegible]eoprene [illegible]ber, a sample of butyl rubber [illegible] literature [illegible]venty experiments are de[illegible] which demo[illegible] some of the important [illegible] the various synthetic [illegible]rs. The purpose of this uni[illegible] acquaint you with the wid[illegible] of synthetic rubb[illegible] today.

Firs[illegible] materials in this unit.

LIQUID LATE[illegible] [illegible]ic vial contains the syn[illegible] [illegible]ion. This is composed of m[illegible] [illegible] Ameripol® rubber [illegible]ed in [illegible]r.

CRUMB [illegible]BER -- The small polyethylene bag contains crumbs of rubber that have been precipitated from the above emulsion.

CONSOLIDATED RUBBER -- The small white block of unvulcanized rubber made by compressing crumb rubber.

NEOPRENE RUBBER -- The white chip of rubber.

BUTYL RUBBER -- The two-inch squ[illegible] rubber one-eighth of [illegible] thick.

<u>Experiment 1</u> [illegible] the [illegible] of rubber latex emulsion furnished in th[illegible] [illegible]NGS. What is its odor? Rub a drop of the emulsion between your fingers. Note the tackiness or stickiness that develops.

An emulsion is a suspension of very fine droplets of an oil in water. In this case the oil is synthetic rubber. One of

the factors that stabilizes an emulsion or suspension of this type is the electric charge that develops on each small droplet or particle. The emulsion becomes unstable and precipitates the synthetic rubber when the electric charge is neutralized. A salt such as common table salt and an acid such as vinegar can be used to precipitate the rubber from this emulsion.

<u>Experiment 2</u> -- Pour the liquid latex into a medicine vial or a very small drinking glass. To this add a few grains of table salt. Stir to dissolve. Then add one teaspoonful of vinegar. Note that the suspension becomes curdled in appearance.

<u>Experiment 3</u> -- Allow this curdled suspension to stand for four hours. Note that the rubber has separated from the suspension at least in part. Feel this precipitated rubber with your fingers. Note its properties. Does it [illegible]etch?

Emulsions are not peculiar to the ru[illegible] industry. They are found in many other instances. One of the most common of emulsions is milk. In this case the cream is emulsified but is not very stable. It separates and rises t[illegible] standing unless the milk has been homogenized. The [illegible]ins are suspended in a much more stable form. They can be precipitated by acidulation just as the rubber emulsion was precipitated.

When milk sours the suspended proteins are precipitated due to the formation of lactic acid. The lactic acid is produced in this case by the fermentation of milk sugar by the lactobacillus. This precipitation can also be accomplished by the addition of vinegar.

<u>Experiment 4</u> -- Fill a drinking glass about one-fourth full with milk. To this add two tablespoons of vinegar. Stir well and allow to stand. Note the curdled appearance of the milk. Does it look like buttermilk?

The crumb rubber furnished in this unit of THINGS was produced by the acidulation of a rubber latex emulsion.

Experiment 5 -- Feel these crumbs with your fingers. Note the springy feeling. Smell them. Do they smell like rubber? Can you stretch them?

Experiment 6 -- Place three of the rubber crumbs in the palm of your left hand. Rub them with the thumb of your right hand until they form a small ball. Drop the ball of rubber on the floor. Note how it bounces.

Experiment 7 -- Place five of the crumbs of rubber on a small piece of aluminum foil. Place the aluminum foil in an oven set at 350 degrees Fahrenheit. Note the effect of an elevated temperature on this raw rubber.

Experiment 8 -- Place five of the rubber crumbs into a cup and pour boiling water over them. Note the effect of this temperature on them. Water boils at 212 degrees Fahrenheit at sea level and somewhat lower at higher elevations.

Experiment 9 -- Place five of the rubber crumbs in a cup. Pour in enough cooking oil to cover them. Allow to stand for three hours. Now take the crumbs out of the oil and compare them with the untreated crumbs. Do they feel different? Do they still stretch as well as before?

The samples of liquid latex, crumb rubber and consolidated rubber in this unit of THINGS were furnished by Goodrich-Gulf Chemicals, Inc. of Cleveland, Ohio.

Natural rubber and most of the synthetic rubbers are adversely affected by oil, gasoline and other petroleum products. A synthetic rubber that is not affected by oil is needed for many uses. Neoprene rubber has been developed to meet this need.

The rubber used in these first nine experiments is of the SBR (Styrene-Butadiene Rubber) type. It has been made by combining molecules of butadiene and styrene. The chemical formulas for these substances are as follows:

$$C_6H_5\text{-}CH{=}CH_2 \qquad CH_2{=}CH\text{-}CH{=}CH_2$$

Styrene Butadiene

$$[\text{-}CH_2\text{-}CH{=}CH\text{-}CH_2\text{-}CH_2\text{-}CH(C_6H_5)\text{-}CH_2\text{-}CH{=}CH\text{-}CH_2\text{-}]_n$$

Styrene-Butadiene Rubber

The chemical formulas show the kinds and numbers of atoms that make up molecules of compounds. In them, C represents a carbon atom and H represents a hydrogen atom. The subscripts such as C_6 indicates the number of atoms of carbon in this case. The "=" or double bond indicates a reactive point in the molecule. These permit the molecule to react with other molecules to form new chemical compounds. The subscript "n" indicates that the chemical formula preceding it recurs a very large number of times forming a very long molecule.

The formula for SBR indicates that the basic unit that recurs contains two butadiene molecules and one styrene molecule. The double bonds that remain in the SBR molecule permit it to react with vulcanizing agents. Vulcanized rubber is more stable at higher temperatures than unvulcanized rubber.

Natural rubber is formed by the rubber tree by combining molecules of isoprene. Many molecules of isoprene are combined to form one molecule of rubber. This process of combining smaller molecules to produce larger molecules is called polymerization. When two or more kinds of molecules are combined as in SBR the process is called copolymerization.

The chemical formulas for isoprene and natural rubber are as follows:

$$CH_2{=}CH\text{-}C(CH_3){=}CH_2 \qquad [\text{-}CH_2\text{-}CH{=}C(CH_3)\text{-}CH_2\text{-}]_n$$

Isoprene Natural Rubber

In 1927 a somewhat satisfactory synthetic rubber was produced in Germany. It was called Buna rubber. The name Buna was derived from the first two letters of the word butadiene and the symbol for the element sodium which is Na. Buna rubber is made by polymerizing butadiene with metallic sodium as a catalyst. Since the formula for butadiene was given previously, we will show only the formula for Buna rubber here.

$$[-CH_2-CH{=}CH-CH_2-]_n$$

Buna Rubber

The first commercially significant synthetic rubber produced in the United States was neoprene. It was introduced in 1931. Neoprene is made by the polymerization of the compound called chloroprene. The chemical formulas for chloroprene and neoprene are as follows:

$CH_2{=}CH-C(Cl){=}CH_2$	$[-CH_2-CH{=}C(Cl)-CH_2-]_n$
Chloroprene	Neoprene

Neoprene is too expensive to use in automobile tires. However, since it is very resistant to organic solvents, oil, chemicals and air oxidation, it finds use in many special items.

Experiment 10 -- Examine the neoprene rubber chip. Does it have a characteristic odor? How much does it stretch? How high does it bounce when dropped to the floor from table height?

Experiment 11 -- Cut a small piece from the neoprene chip. Place it in a cup and pour enough cooking oil in to cover the piece. Allow this to stand for three hours. Has the oil affected the neoprene rubber? Is it softer? Does it stretch more or less? Compare this with the effect of oil on the crumbs of rubber.

Now you can see why neoprene is used for gasoline hoses and for shoe soles in gasoline stations. Neoprene is valued highly for this property.

Experiment 12 -- Repeat Experiments 8 and 9 using small pieces of the neoprene rubber in place of the rubber crumbs. Does neoprene resist higher temperatures better than SBR?

The neoprene sample was furnished by E. I. Du Pont de Nemours & Co., Inc. of Wilmington, Delaware.

The block of consolidated rubber is SBR just as the crumbs of rubber.

Experiment 13 -- Repeat Experiments 5, 6, 7, 8, and 9 using small pieces of the consolidated rubber instead of the rubber crumbs. How do the results compare?

During World War II the United States Government assisted in the establishment of the modern synthetic rubber industry in this country. To aid the defense efforts factories were built to produce the needed rubber substitutes. The plants were later sold to private companies.

The synthetic rubber produced in largest quantities in these plants was Buna S or GRS (Government Rubber - Styrene). This is the rubber that is called SBR today.

The successful production of good synthetic rubbers was due to the discovery of emulsion polymerization. This process permits the combination of the molecules of two or more substances in variable quantities to produce the large molecules needed in synthetic rubber. This enables one to produce synthetic rubber with the specific properties desired for special purposes.

Each of the synthetic rubbers has its own properties which make it useful for certain application. Buna S, GRS or SBR has been most extensively used for automobile tires.

Neoprene rubber or GRM has been used most widely for objects that are exposed to gasoline, oil or other organic solvents.

In emulsion polymerization, the compounds to be combined are emulsified by the use of a soapy solution. A catalyst is added which is usually an organic peroxide. The catalyst causes the molecules of the compounds to combine forming a copolymer. The synthetic rubber is formed as a stabilized water emulsion or suspension.

Experiment 14 -- You can illustrate the formation of an emulsion in your kitchen with readily available materials. To a glass half-filled with water add three drops of cooking oil. To this add a small amount of soap powder or liquid soap. Stir the mixture well. Note the white emulsion that develops. The soap acts as an emulsifying agent.

Experiment 15 -- This emulsion can be precipitated by adding vinegar. To this white emulsion add vinegar until the white color changes.

A more recent development in the synthetic rubber industry has been butyl rubber. It is produced by the polymerization of isobutylene with butadiene. The formulas for isobutylene and butyl rubber are as follows:

$CH_2{=}C(CH_3)_2$	$[-CH_2-C(CH_3)_2-CH_2-CH{=}CH-CH_2-CH_2-C(CH_3)_2-]_n$
Isobutylene	Butyl Rubber

Butyl rubber or GRI (Government Rubber - Impervious) is very impervious toward gases. Since it does not let air leak out it has been widely used for the inner tubes of automobile tires. Some automobile tires are now made of butyl rubber.

Experiment 16 -- Remove the blue backing from the piece of butyl rubber. Examine it carefully. Note its odor. How far will it stretch? Stretch this piece of rubber until it breaks.

Experiment 17 -- Roll the rubber into a ball. Drop this little ball to the floor from table height and see how high it bounces.

Experiment 18 -- Cut off a small piece of the butyl rubber. Put it into a cup with a small amount of cooking oil. Allow to stand for three hours. Has the oil affected the butyl rubber? How does this compare with the effect on neoprene and SBR?

Experiment 19 -- Repeat Experiments 7 and 8 using small pieces of butyl rubber. How does butyl rubber compare with SBR and neoprene in resistance to higher temperatures? The butyl rubber sample was furnished by Enjay Chemical Co., a Division of Humble Oil & Refining Co., of New York, N. Y.

One of the most important properties of rubber is its resistance to abrasion. This is particularly important when it is used in automobile tires. We like to buy tires that will last many thousands of miles before they wear out. This requires a large resistance to abrasion.

Experiment 20 -- You can check the resistance to abrasion of the consolidated SBR, the neoprene rubber and the butyl rubber in the following manner. With a small piece of sandpaper or emery cloth, rub each of these samples of rubber with the abrasive. Note which appears to have the greatest abrasive resistance.

The largest single usage of synthetic rubber is in automobile tires. Here the properties to be desired are resistance to abrasion, high temperatures and the lack of heat build-up during use.

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Production by Burrell Wood

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